Chapter 8

DESIGNING FOR PEDESTRIANS

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Walking is not usually considered a transportation mode. Perhaps this is because it does not employ vehicles or because it is such a fundamental means of movement. But walking is actually the most vital mode of transportation upon which all societal activities depend. Upright human locomotion has been recognized as our most significant evolutionary accomplishment—a unique physical skill that eventually led to the technological triumph of the "walk" on the moon. Walking has been interwoven into all aspects of human development. The first cities were organized to concentrate the means of survival within a convenient walking distance. Even in the mechanized society of today, walking is the primary means of internal movement within cities. It is the only means of attaining the necessary face-to-face interaction involved in all the commercial and cultural activities that comprise the urban milieu. With the exception of cycling, walking is the only means of human movement by which we can dramatically experience the sensory gradients of sight, sound, and smell that define a place.

As a means of transportation, walking has many important attributes directly related to the quality of life. Walking provides a versatile linkage between other transportation modes that would be impossible to duplicate. The practical range of human walking distances determines the effective service area, convenience, and utility of transit systems. As a transportation mode, walking offers predictable travel times; continuous availability; ubiquitous and easily maintainable routes; reliable, free, nonpolluting, non- energy-consuming service; and, for many, healthful, relaxing exercise. The pedestrian mode is gaining recognition as a basic building block in urban system design. Increasing attention is being given to developing vehicle-free zones to reduce urban pollution and return the inner city to its former role as a place for personal interaction. Attempts are being made to improve the walking experience, to make it more safe, convenient, and attractive.

Transit station effectiveness is determined by the ability of the modal interface to accommodate pedestrian movement. Station planners and operators must understand pedestrian traffic characteristics to provide a convenient and safe passenger environment. This understanding requires knowledge of pedestrian speeds, traffic flow relationships of corridors and stairs, escalators, platforms, and fare processing rates. Analytical techniques available to evaluate pedestrian facilities include *level-of-service (LOS) standards*, a series of measures that defines relative degrees of convenience for different pedestrian traffic volumes and densities, and the *time-space (TS)* analysis method, used to evaluate complex spaces such as platforms and fare-control areas where both waiting and walking can occur simultaneously. The technique compares a TS supply, consisting of the product of the analysis period and the functional area available, and the TS demand created by passengers walking and waiting in the area during this period.

HUMAN FACTORS AND BEHAVIORAL ASPECTS

Human body dimensions, locomotion characteristics (both walking and using stairs), and behavioral preferences help to establish the requirements for accommodating pedestrians safely and conveniently. Human locomotion involves many complex skills of balance, timing (gait, perception, and reaction), and vision that are often taken for granted except by the physically impaired. Natural unimpeded walking requires a uniform, nonslip walking surface and sufficient space both laterally and longitudinally to avoid conflicts with others. The width of the human body plus allowance for body sway determine lateral spacing, and individual pacing distance combined with perception and reaction times, the longitudinal spacing. Vision plays an important role in locomotion to perceive and react to variances in the walking surface and to avoid conflicts with others.

WALKING CYCLE

The human walking cycle begins by leaning forward and swinging the leading foot into a heel strike. At about the same time the rear foot begins a rolling push-off and is swung forward for a new heel strike and a repeat of the cycle. Walking speed is determined by stride length, pacing rate, and shifts in the body center of gravity. Sufficient surface friction is necessary at the heel strike of the forward foot and rear foot push-off to avoid slipping, and a uniform surface is needed on the follow-through to avoid tripping. Surface friction values of 0.5 or better are desirable for flooring materials in public transit facilities.

MOVEMENT ON STAIRS

Stair climbing and descent are quite different from walking. When climbing stairs, the body center of gravity is shifted forward, the leading foot is placed on the tread above, and both the leading and rear legs combine for the push-off to lift the rear foot to the next tread above. In descent the body center of gravity is shifted backward, the lead foot is placed on the step below, and the rear foot lifted, swung forward and placed on the next step below. Most accidents on stairs occur in the down direction, and these accidents are usually more severe because of the greater energy and impact of the fall.

People using stairs cannot select their natural pace because the tread width dictates the same pace length for all persons. The stair riser changes patterns of leg and body movement, requiring greater bending of the knee and more careful balance. These differences, combined with increased energy demands, inconvenience many who otherwise have little difficulty walking.

RAMPS

Sometimes used as an alternative to stairs, ramps have a higher traffic capacity as the same width stair, but occupy much greater area because of their more gradual slope. Ramps up to a slope of approximately 3% are perceived to be almost level by most pedestrians, and slopes of up to 10% for short distances are considered acceptable, except for wheelchair use, for which slopes are limited to 8.33% by most authorities. Sidewalk slopes exceeding 20% occur in cities such as San Francisco and Seattle. Surface friction values are reduced on sloped surfaces and may require special treatment to avoid slipping hazards.

PERSONAL SPACE PREFERENCES

Human behavioral factors, including personal space preferences and interactions with others, are important in understanding pedestrian requirements. People prefer to avoid contact with others except where such crowding is unavoidable. At poorly managed public events, excessive crowding at extreme densities equaling the area of the human body, has resulted in mass fatalities. Crowd management may be necessary in transit facilities when unusual demands occur, for example, after a sporting event or parade.

The plan view of the human body can be viewed approximately as an ellipse defined by the body depth and shoulder breadth measurements. Human factors studies have shown that the fully clothed dimensions of the 95th percentile of the population (95% are less than this) are 13 in (330 mm) body depth and 23 in (580 mm) shoulder breadth. The plan view of the average male human body occupies an area of approximately 1.5 ft2 (0.14 m2). A 18 x 24 in body ellipse equivalent to a standing area of 2.3 ft2/pr has been used by the New York City Transit Authority to determine the standee capacity of its subway cars. This level of crowding results in unavoidable physical contact by passengers, which can be psychologically disturbing for some persons. Observations of crowding in elevators has shown that unavoidable contact with others begins at personal space occupancies of 2.75 ft2/pr.

Behavioral experiments involving personal space preferences have shown minimum desirable occupancies ranging between 5 and 10 ft2/pr, where physical contact with others is avoidable. As a point of reference, an opened 30-in (760-mm)-diameter umbrella covers an area of about 5 ft2 (0.5 m2). The larger personal space preferences are observed in crowded queues, whereas occupancies involving physical contact occur only in the most crowded elevators and transit vehicles.

SPACE FOR MOVEMENT

The characteristics of human movement, body dimensions, and personal space preferences are useful for understanding pedestrian traffic relationships. Considering the width of the human shoulders, body sway, and avoidance of contact with others, people require a lateral space of 28 to 30 in (710 to 760 mm) for comfortable movement. The longitudinal spacing for walking, including space for pacing and avoiding conflicts, would be 8 to 10 ft (2.5 to 3 m). This results in a minimum personal area of 20 to 30 ft2/pr (2 to 3 m2/pr) for relatively unimpeded walking in groups on level surfaces Much smaller personal areas are observed in queues and other crowded situations where movement is restricted. The personal space required for comfortable movement on stairs is less than walking because of the limitations imposed by the treads and concerns for safety. People need to attend to only about 2 to 3 treads ahead when using stairs; this equates to a minimum personal area of about 10 to 20 ft2/pr for stair movement. The personal spaces required for comfortable movement help us understand the traffic relationships and design standards that are presented later in this chapter.

PEDESTRIAN CHARACTERISTICS

The primary characteristics needed to evaluate pedestrian facilities are walking speeds, walking distances, demand patterns, and traffic-flow relationships. The ability of pedestrians to select their own individual walking pace and speed is a qualitative measure of convenience. Walking distances define the effective service area of transit stations, with shorter distances improving passenger perceptions of service and convenience. The patterns of passenger demand affect the methods used to analyze pedestrian facilities and the applications of service standards.

WALKING SPEEDS

Pedestrian speeds, in addition to being directly related to traffic density, have been found to vary for a wide range of conditions, including individual age, sex, personal disabilities, environmental factors, and trip purpose. Normal walking speeds unimpeded by pedestrian crowding have been found to vary between 150 and 350 ft/min (0.76 and 1.76 m/s), with the average at about 270 ft/min. As a point of comparison, running the 4-min mile is equivalent to a speed of 1320 ft/min or almost 5 times normal walking speed. Walking speeds decline with age, particularly after age 65, but healthy older adults are capable of increasing their walking speed by 40% for short distances. Dense pedestrian traffic has the effect of reducing walking speed for all persons. The smaller personal space limits pacing distances and the ability to pass slower moving pedestrians or to cross the traffic stream.

Photographic studies of pedestrian traffic flow on walkways have shown that individual area occupancies of at least 35 ft2/pr (3 m2/pr) are required for pedestrians to attain normal walking speeds and to avoid conflicts with others. Interestingly, the maximum pedestrian traffic-flow volume is not obtained when people can walk the fastest, but when average area occupancies are at about 5 ft2/pr, and pedestrians are limited to an uncomfortable shuffling gait less than half normal walking speed. At individual space occupancies below 2 ft2/pr, approaching the plan area of the human body, virtually all movement is stopped. When there is a large crowd in a confined space, this density can result in shock waves and potentially fatal crowd pressures.

SPEEDS ON STAIRWAYS

Movement on stairways is restrained by tread and riser dimensions, added exertion, and greater concerns for safety. These restraints result in lower speeds and lower traffic capacity on stairways than on walkways. Ascending stair speeds vary from 50 to 300 ft/min, with the average at about 100 ft/min, or one-third level walking speed. Descending speeds are about 10% faster than ascent because of the assist of gravity. A much wider variation of individual speeds exists on stairways because even minor vision or joint disabilities can significantly affect climbing or descending movements. For this reason greater attention to human factors and safety requirements is required in stairway design. Most building codes use a 22-in (560-mm) lane width as an egress standard, and multiples of this width are often used in designing stairs. This arbitrary selection can result in inconveniently narrow stairs, particularly in transit facilities where there is heavy two-way movement and people with hand-carried articles. Based on human factors considerations, lane widths on stairs in transit facilities should be in multiples of 28 to 30 in (711 to 760 mm), with a minimum width of 60 in needed for fluid two-way movement.

STAIRWAY DESIGN

Other design details that are frequently misunderstood are the dimensions of stair risers, treads, and handrails. Excessively steep stairs are sometimes specified to simplify structural framing and reduce construction costs. This false economy penalizes all users of the stairway for the life of the building and can be unsafe. Recognizing user safety and convenience issues, designers are typically using lower risers and wider treads than in the past. Risers as low as 5 in (130 mm) and treads as wide as 14 in (360 mm) are being specified to provide more convenient leg movement and added space for foot placement. The serviceability of more gently sloped stairs has been amply proved by a 6-in riser and 14-in tread-width stair in constant heavy use for more than 50 years in New York's Pennsylvania Railroad Station.

Stairway handrails are an important safety consideration because the handrail may be the only means of stopping a serious descending fall. Handrails should be *reachable* to anyone on the stair and *graspable*, with an ideal gripping circumference. These considerations translate to a maximum width of 60 in (1520 mm) between handrails and a handrail circumference of 4.4 to 5.2 in (112 to 132 mm), which is equal to a cylindrical handrail 1.4 to 1.7 in (36 to 42 mm) in diameter or the rounded shape equivalent. Handrails should also be at the greatest height allowable by code, extended past landings to aid the disabled and where there is an exposure to a fall to a lower level, supplemented by guardrails at least 42 in (1070 mm) in height. Lighting on stairs should be of good quality to avoid shadows and glare and, preferably, should be at least 270 lux (25 foot- candles).

WALKING DISTANCE

As with many other aspects of pedestrian behavior, human walking distances vary significantly according to trip purposes and the environmental setting. Numerous surveys of automobile drivers show preferred parking locations within 500 ft (152 m) of their destination, about a 2-min walk, but the auto provides the means of getting even closer to that destination. Interestingly, drivers will go to great lengths to obtain a parking spot close to the entrance of a shopping mall, but have no problems walking 1 or 2 mi within the mall itself. Walking distances within major museums can often exceed 3 mi (5 km).

Transportation planners generally use about 0.25 mi (0.4 km), approximately a 5 min walk, as the acceptable walking distance to transit stops, beyond which another connecting mode is required or public transit will not be used for the trip. There is evidence, however, that much longer walking distances are accepted in larger cities. A study conducted in downtown Boston indicated that 60% of walking trips were greater than 0.25 mi and 18% beyond 0.5 mi. Average walking distances in Manhattan were found to be 1720 ft (524 m), with a median at 1070 ft. Higher average walking distances were found for passengers at the New York Port Authority Bus Terminal. About one- third of all departing passengers walk to this terminal, and the remainder use other connecting modes. Virtually all passengers within 1000 ft of the Port

Authority Terminal walk to it, within 1 mi about half walked and half used another connecting mode, and at 1.5 mi, 10% walked.

These data show that the limits of human walking distance are more situation related than energy related. Nevertheless, in specific situations such as modal transfer facilities where the passenger places a magnified value on *time*, walking distances should be kept as short and direct as possible. This policy has the added benefit of reducing signing and other information requirements.

DEMAND CHARACTERISTICS

It is important for the transportation analyst to thoroughly understand the traffic patterns associated with any pedestrian facility. For example, traffic flow is intermittent on sidewalks because of interruptions by traffic signals or in transit terminals due to the intermittent arrivals of trains. Also, there are differences between arriving and departing peaks in transit terminals. In the arriving peak, large volumes of passengers are discharged from trains in a short period, typically placing maximum demand on pedestrian facilities. In the departing peak, passenger arrivals at the platform are more gradual, making the available platform space for queuing the important consideration.

PEDESTRIAN TRAFFIC-FLOW EQUATION

The volume of pedestrians that can be accommodated on walkways and stairs is related to traffic density and the average speed attainable at that density. *Pedestrian density*, typically expressed in pedestrians per unit of area (ft2 or m2) is an unwieldy unit and difficult to visualize, so the reciprocal, area per pedestrian (ft2/pr or m2/pr) is preferred for analysis. The fundamental pedestrian traffic flow equation for walkways and stairs is expressed in Eq. (8-1).

$$f = s/a \qquad (8\text{-}1)$$

= volume in pedestrians per foot- or meter-width of traffic way per minute (pr/ft-min or pr/m-min)
average pedestrian speed (ft/min or m/min)
average area per pedestrian within the traffic stream (ft2/pr or m2/pr)

Example: At the near average normal walking speed of 250 ft/min (1.26 m/s), average pedestrian space is 25 ft2/pr (2.32 m2/pr), and the flow per foot of effective corridor width is 10 pr/min (0.54 pr/s-m).

Equation (8-1) is based on an analogy to hydraulic flow in channels and therefore is only applicable where there is continuous and reasonably uniform pedestrian movement. In spaces where uniform flow does not exist and where there are other activities such as queuing, alternative analytical techniques such as the time-space (TS) method must be used.

TIME—SPACE ANALYSIS

The pedestrian traffic equation and the LOS standards presented in the following sections are applicable to corridors where pedestrian traffic flow is moving uniformly. There are many other types of pedestrian spaces, however, where flow is not strictly uniform, people may combine other activities with walking, such as queuing, or traffic flow is multidirectional. In these situations some pedestrians may spend only a brief time in the space by directly walking through it, whereas others may spend longer times both walking in it and performing other functions. The space necessary to perform these functions may also vary.

Time—space (TS) analysis can provide a better understanding of the dynamics of these more complicated spaces by combining the knowledge of personal area occupancies developed in the LOS standards with a more discrete analysis of pedestrian activities. With the TS method, the product of the time of the analysis period, for example, the peak 15 min, and the area of the analysis space in ft2 or m2 establishes a TS *supply*. The *demand* for this TS supply is determined by the product of the total number of pedestrians using the analysis space and their time of occupancy.

The typical application of the TS method is the evaluation of the adequacy of a space where there is a forecasted peak-period pedestrian demand, the configuration and area of the space are known, and occupancy times for pedestrian functions such as walking or waiting can be predicted. The average area per pedestrian and LOS under these conditions can be obtained by dividing the TS demand into the TS supply. This is expressed in Eq. (8-2).

$$a = \frac{TS\,\mathrm{sup}\,ply}{TSdeman} = \frac{TS}{nt} \qquad (8\text{-}2)$$

where a = average area per pedestrian (ft2/pr or m2/pr) within the analysis space, during the analysis period

T = time of the analysis period (min)

S = net effective area of the analysis space (ft2 or m2)

n = number of perdestrians occupying the space or performing discrete functions in the space such as walding, waiting, or ticket purchase

time of the analysis period (min) net effective area of the analysis space (ft2 or m2) number of pedestrians occupying the space or performing discrete functions in the space such as walking, waiting, or ticket purchase

t = predicted occupancy times of pedestrians for functions performed during the analysis period

Example: During a 15-min peak, 1500 passengers pass through a 2500-ft2 area fare-control space. Average walk time through the space is 15 s. One-quarter of these passengers spend an additional 10 s waiting in line to purchase transit tokens. What is the average area per person during the peak 15-min period?

$$TS\sup ply = TS = (15\min)(2500\,ft^2) = 37{,}500\,ft^2 - \min$$

$$TSdemand = nt = \frac{\{(1500)(15s)\} + \{(1500)(0.25)(10s)\}}{60s/\min} = 437.5\,pr - \min$$

$$a = \frac{TS\sup ply}{TSdemand} = \frac{37{,}500\,ft^2 - \min}{437.5\,pr - \min} = 85.7\,ft^2/pr$$

This relationship can also be used to determine corridor widths where desired LOS and area per person are specified, the length of the corridor section is known, and where the times for walking through the corridor section, waiting in lines, obtaining information, or other functions can be predicted. Equation (8-2) would have the following form when the TS method is used to determine corridor widths:

$$w = \frac{ant}{Tl} \qquad (8\text{-}2)$$

where w = corridor width (ft or m)
l = corridor length (ft or m)

Example: Determine the width (w) of a 100-ft (30.5-m)-long (l) corridor with a predicted flow of 200 (n) people per minute where the walking speed is estimated at 4 ft/s (1.2 m/s), and it is desired that the average area per person (a) be 25 ft^2/pr (2.3 m^2/pr). Note that t is 25 s or 0.42 min; T = 1 min.

$$w = \frac{(25)(200)(0.42)}{(1)(100)} = 21\,ft(6.4m)$$

APPLICATIONS TO TRANSIT STATION DESIGN

The LOS standards and TS analysis procedures presented in this chapter can be used to design new transit stations or to evaluate the relative convenience of existing stations. The New York City Planning commission requires this type of analysis as part of the environmental impact statement (EIS) procedure for the approval of new building projects. As previously noted, it is important to have a thorough understanding of pedestrian traffic demand characteristics so that the LOS standards are not misapplied or misinterpreted.

For example, in the arrival mode at heavily used transit platforms, stairs and escalators will be used to maximum capacity until all arriving passengers are accommodated. It is important in this condition to evaluate average passenger waiting times, queue lengths and queuing areas, and the overall platform clearance time. Minimum standards for these conditions could consist of clearance of the platform before the next train arrival and average pedestrian waiting times not to exceed the escalator trip time or stair-use time.

Analysts and students are encouraged to make their own observations of the use of pedestrian facilities, potentially to modify analytical techniques to provide a better model of observed conditions or service standards for levels of crowding and convenience appropriate to local norms.

CORRIDORS

Walkways have significant pedestrian traffic capacity, but the provision of too narrow walkways should be avoided because of human factors and user convenience considerations. Two persons walking abreast require a width of 5 ft (1.5 m) to walk comfortably. Considering that transit facilities can experience heavy two-way traffic movement, minimum corridor widths of 10 ft are indicated. Also, LOS standards are based on the net effective width of the walkway, requiring that 6 in (150 mm) be added to each edge to account for the avoidance of walls. Consideration also must be given to reductions in effective corridor width where doors open into the corridor, where there are columns, or where there are other conflicts such as the extension of queue lines into the traffic stream.

STAIRWAYS

The traffic capacity of a stairway is less than the equivalent-width walkway, frequently resulting in pedestrian queuing at stair approaches. For this reason, the approach configuration should be given careful consideration. The minimum-width stair in transit applications should be 5 ft to provide for convenient two-way, single-file movement. Wherever possible, wider stairs should be provided. The net effective width of stairways is clear distance between handrails. Stairways in transit applications are subjected to two different types of demands. In the departure peak, demands are more nearly uniform throughout the peak period. In the arrival peak, however, large numbers of passengers can be unloaded from trains in very short periods, causing stairs to be overloaded and queuing to develop. During these periods stairways will operate at full capacity, or LOS E. In the arrival situation, pedestrian delay times, queue size, and platform clearance times become convenience measures rather than crowding density.

FARE-CONTROL AREAS

Time—space analysis of fare-control areas, for example, to determine the average pedestrian LOS during the 15-min peak period, requires a determination of the effective usable area in the fare-control section; the total numbers of people passing through the section; the proportion of those purchasing tickets, requesting information, or waiting at turnstiles; and the predicted times for performing these activities. Average area per person and LOS for the peak period are determined by adding all the various demands in pedestrian minutes and dividing it into the TS supply.

TRANSIT PLATFORMS

Passengers using transit platforms in the departure mode distribute themselves on the platform by walking from a connecting stairway or escalator to a position where they stand and wait for the train. Passenger distribution on the platform may not be uniform, and this might have to be taken into consideration. Some platforms may also need to accommodate passengers transferring across the platform from other trains. Platforms can be analyzed for a peak period or for the headway in minutes between trains. Passenger time—space demand consists of the product of the number of passengers using the platform and their average walk and wait times. It should be emphasized that the area per pedestrian and LOS for the platform is an average for the analysis period. It is advisable, particularly where platforms are heavily used, to examine the maximum occupancy of the platform that occurs just before train doors open to accept passengers. If this maximum occupancy is below queuing LOS C, it is desirable to add train service and reduce headways to avoid potentially dangerous crowding.

PEDESTRIANS LEVEL-OF-SERVICE STANDARDS

Traffic standards have been developed for both walkways and stairways based on photographic studies of pedestrian movement on these facilities. The standards define flow relationships for various volume levels and average personal areas and related qualitative attributes such as the ability to bypass slower moving pedestrians and to avoid conflicts with others. These standards have been classified into various levels of service (LOS) ranging from A to F, with LOS A representing the threshold of unimpeded free flow and with LOS F at critical density or breakdown of movement continuity. LOS standards have also been developed for waiting areas, such as transit platforms, based on pedestrian densities and relative degrees of mobility within the waiting area. Care must be taken when applying these standards to facilities where the demand is such that capacity will invariably be exceeded for short periods. An example is a transit platform where potentially more than 1000 passengers could be discharged onto the platform in less than a minute. In such facilities, platform clearance times or average pedestrian delay may provide a more realistic standard of service, since typically all facilities would be operating at maximum capacity. It should be noted that all the LOS walkway and stairway standards represent heavy pedestrian traffic flow conditions, which in other nontransit environments may be considered to be too crowded.

WALKWAY LOS

Relationships for walkway volumes and density at LOSs A to F are illustrated graphically in Fig. 8-1. Standards for walkway traffic volumes, area per person, speed

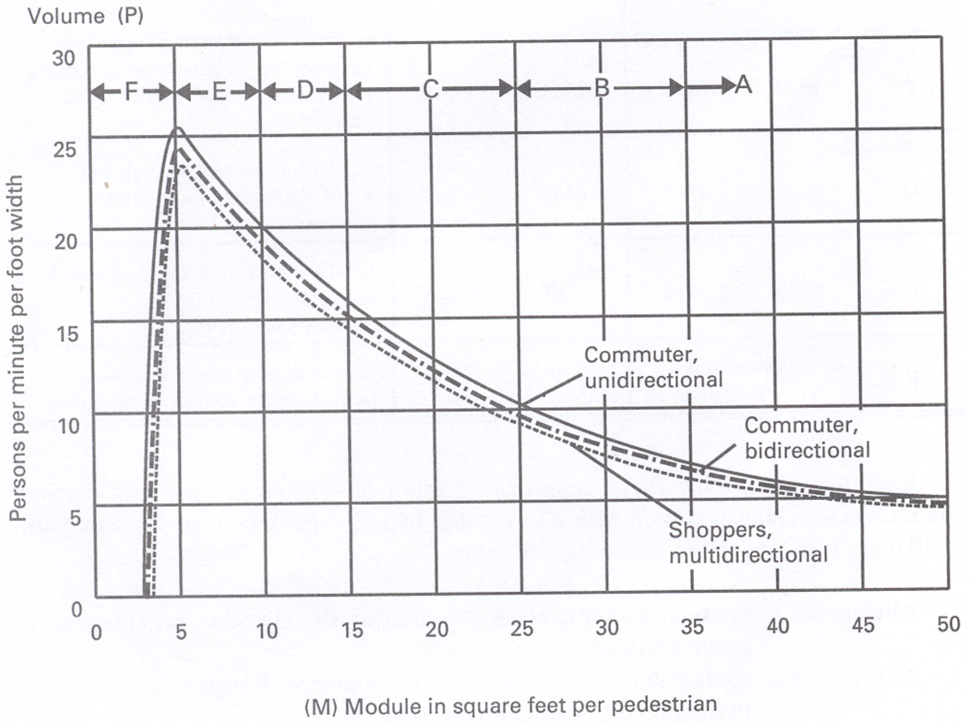


Figure 8-1 *Level-of-service standards for walkways—volume versus module.*

data, and qualitative descriptions of related traffic conditions for walkway LOSs A to F are also summarized in Table 8-1. Traffic-flow standards are applicable only to the net effective width of the walkway, deducting any obstructions in the walkway space and taking into account that pedestrians do not walk close to corridor walls. Typically, pedestrians will keep about 6 in (150 mm) away from walls and columns in indoor environments and up to 18 in from walls and curbs in outdoor locations. Where there are doors opening into corridors, persons accessing change machines, or other functions that would reduce the net effective width available for movement, added reductions may be necessary.

TABLE 8-1

Walkway Level of Service Descriptions

LOS	Ped. Volume (f) min pr/ft	pr/m	Average Area (a) ft2/pr	m2/pr	Description
			35 or more	3.3 or more	
A	7 or less	23 0r less	35 or more	3.3 or more	Threshold of of free flow, convenient passing, conflicts avoidable.
B	7-10	23-33	25-35	2.3-3.3	Minor conflicts, passing and speed restrictins.
C	10-15	33-49	15-25	1.4-2.3	Crowded but fluid movement, passing restricted, cross and reverse flows difficult.
D	15-20	49-66	10-15	0.9-1.4	Significant conflicts, passing and speed restrictions, inter- mittent shuffling.
E	20-25	66-82	5-10	0.5-0 9	Shuffling walk; reverse, passing and cross flows very difficullt; intermittent stopping.
F	Flow varialbe up to maximum		5 or less	0.5 or less	Critical density, flow sporadic, frequent stops, contacts with others.

Example: Determine the recommended width of a 200-ft (61-m)-long corridor connection to a transit station with a forecasted two-way, peak-hour pedestrian traffic of 10,000 pr/h under the following conditions:

Example: Determine the recommended width of a 200-ft (61-m)-long corridor connection to a transit station with a forecasted two-way, peak-hour pedestrian traffic of 10,000 pr/h under the following conditions:

ve 1: commuters only, no doors entering the corridor, no columns, no other services.

2: same volume, but with retail development along the corridor edges in a shopping mall configuration.

Solution for Alternative 1: This requires the selection of a design LOS and appropriate design peak. Unless there are significant restraints, the approximate mid-range of LOS C, or 12.5 pr/ft min, is an appropriate standard. The 15-min peak, typically about 40% of peak-hour volume, is an appropriate design period.

$$Neteffectivewidth = \frac{(10{,}000\,pr)(0.40)}{(15\,\text{min})(12.5\,pr\,/\,ft - \text{min})} = 21.3\,ft$$

Add edge effect= (2)(6 in) = 1.0 ft
Total = 22.3 ft

Recommended corridor width = 22.3 ft (6.8 m)

Solution for Alternative 2: The shopping mall alternative can be analyzed as (a) a corridor with additions at the edges to allow window-shopping and door-opening "lanes" or (b) on a time-space basis, assuming some percentage of the commuters will spend additional time in the corridor. For illustrative purposes, it will be assumed that 100% of the commuters walk through the corridor, but that 30% of this total stop to window-shop for an additional 1 min each. It is desired to provide a density of 20 ft2/p average within the corridor during the 15-min peak.

(a)

$$Neteffetivewidth = \frac{(10{,}000\,pr)(0.40)}{(15\,\text{min})(12.5\,pr\,/\,ft - \text{min})} = 21.3\,ft$$

Add edge effect doors = (2)(3 ft) = 6.0 ft
Total = 27.3 ft

Recommended corridor width = 27.3 ft (8.3 m)

(b) The *TS supply is* the product of the 15-min time of the analysis period, the corridor width (w), and the length (I) of 200 ft. Refer to Eq. (8-3).
TS supply = (w)(200 ft)(15 min) = 3000 w (area-min)
The *TS demand is* the time required to walk through the corridor at an assumed walking speed of 250 ft-min (0.8 min), plus the time spent window-shopping.
Walk time = (10,000)(0.4)(0.8 min) = 3200 pr-min
Shop time = (10,000)(0.4)(0.30)(1 min) = <u>1200 pr-min</u>
Total = 4400 pr-min

$$TSdemand = (4400\,pr - \min)(20\,ft^2 / pr) = 88{,}000\,ft^2 - \min$$

TS supply = TS demand

3000w - 88,000 ft2-min

$$w = \frac{88{,}000}{3000}$$

w = 29.3 ft (8.9 m)

Recommended corridor width = 29.3 ft (8.9 m)

You will note that the two different methods give roughly similar results under rather different assumptions. However, the TS method provides greater flexibility to input more variations in pedestrian behavior and to do sensitivity analyses of the impact of these variations on proposed designs.

STAIRWAY LOS

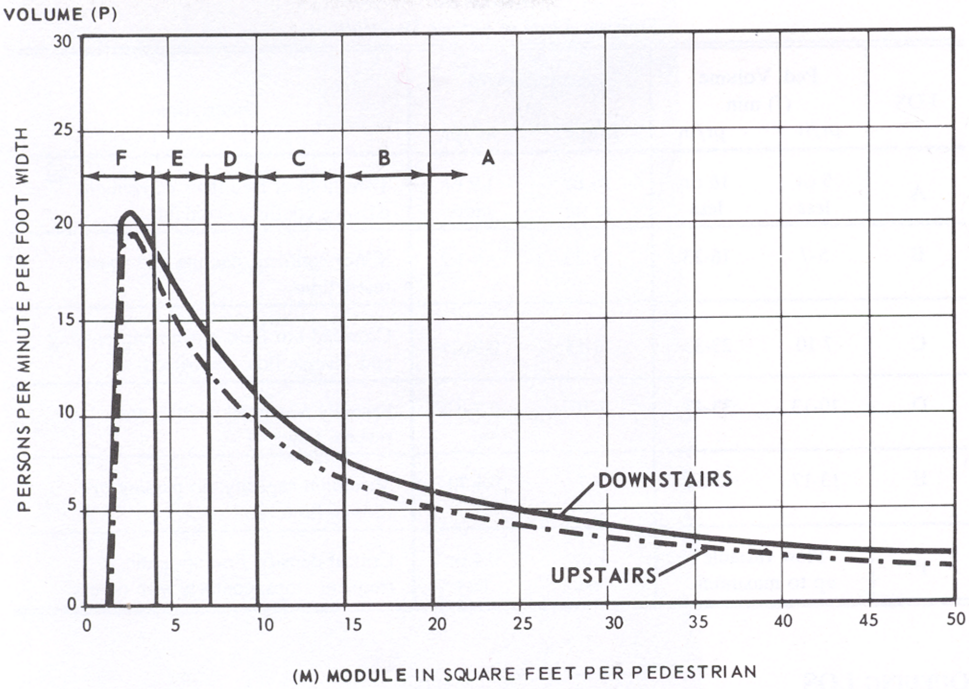
Flow relationships for stairway volumes and densities at LOSs A to F are illustrated graphically in Fig. 8-2. A summary of volume, area per person, speed, and a qualitative description of flow conditions at these various levels of service are shown in Table 8-2. Stairway volume data must also be applied to the effective width of the stairway, not the overall width. The net effective width of the stairway is the clear distance between handrails. The adequacy of queuing space at stair approaches, particularly at upper landings, should be examined in relation to expected volumes of traffic to avoid excessive and potentially dangerous crowding.

Example: Determine the width of stairs required on a 600-ft (183-m)-long, 20-ft (6.1-m)-wide, side-loading transit platform to accommodate a departure volume of 10,000 peak-hour passengers and an arrival volume of 1500 passengers on the most crowded peak train. The peak-period headway between train arrivals is 5 min.

Solution for the departure peak: The departing peak-hour passengers arrive on a more gradual basis, typically 40% in the peak 15 min. The appropriate LOS for this condition is stairway LOS C, with a midrange design flow of about 8.5 pr/ft-min (28 pr/m- min). Note that the effective width equals the clearance between handrails.

$$\text{Total effective stair width} = \frac{(10{,}000)(0.4)}{(8.5\,pr/ft - \min)(15\min)} = 31.4\,ft$$

Alternatives: Two 16-ft end stairs or three 10.5-ft stairs



metric conversion: 1 ft = .3m, 1 ft² = .0 9 m².

Figure 8-2 *Level-of-service standards for stairways—volume versus module.*

Solution for the arriving peak: The typical transit car configuration, with up to three sets of wide double-doors per car opening simultaneously, has the capability of discharging 1500 passengers in a minute. All stairways are almost immediately subjected to LOS E capacity conditions or a flow of 17 pr/ft-min (56 pr/m-min). The desirable standard is that the platform be cleared before the next peak-train arrival or sooner. The trial design width selected for the departure peak will be tested for its ability to accommodate the arriving peak train.

$$\text{Capacity of stairs} = (31.4\ \text{ft})(17\ \text{pr/ft-min}) = 534\ \text{pr/min}$$

$$\text{Platform clearance time} = \frac{1500\ \text{pr}}{534\ \text{pr/min}} = 2.8\ \text{min}$$

The clearance time is less than the train headway of 5 min, and therefore the design is satisfactory for both arriving and departing peaks.

TABLE 8-2
Stairway Level of Service Descriptions

LOS		**Pe. Volume** (f) min pr/ft	pr/m	**Average Area** ft2/pr	(a) m2/pr	Description
A	5 or less	16 or less	20 or more	1.9 or more		Threshold of free flow, convenient passing, conflicts avoidable.
B	5-7	16-23	15-20	1.4-1.9		Minor conflicts, passing and speed restrictions.
C	7-10	23-33	10-15	0.9-1.4		Crowded butr fluid movement, passing and and reverse flows restricted.
D	10-13	33-43	7-10	0.7-0.9		Serverly restricted passing and reverse flow.
E	13-17	43-56	4-7	0.4-7.0		Maximum capacity, no passing or reverse flow.
F	Flow variable up to maximum		4 or less	0.4 or less		Critical density, flow sproadic, frequent stops, contacts with others

QUEUING LOS

The provision of inadequate space where pedestrian waiting occurs can cause problems ranging from temporary inconvenience and discomfort to crowd-induced falls and other hazards. Queuing often occurs in transit stations on platforms; at escalators, stairs, turnstiles, doors, and ticket dispensing machines; and at any location where passengers may be delayed, even momentarily. Queues may be classified into two general types, the *linear* or *ordered queue, in* which pedestrians line up and are served in their order of arrival, and the *undisciplined* or *bulk queue*, where there is more general, less ordered crowding. The spacing between persons in linear queues is surprisingly uniform and consistent with behavioral studies of personal space preferences. In disciplined linear queues the interpersonal spacing is 19 to 20 in (480 to 500 mm), and the recommended lateral single-file width for railings or other dividers is 30 in (760 mm).

Interpersonal spacing and area occupancies in undisciplined bulk queues are naturally more variable and are therefore rated according to the degree of mobility within the queuing space at different pedestrian densities. For example, on transit platforms it is necessary to provide sufficient space not only for passengers to stand and wait, but also for others to move through these standees and distribute themselves along the platform. Queuing LOSs based on pedestrian area occupancies and relative degrees of mobility within the waiting space are summarized in Table 8-3.

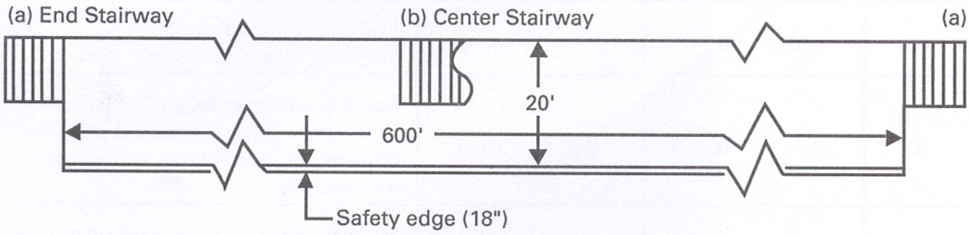
TABLE 8-3
Queuing Level of Service Descriptions

LOS	Average Area ft²/pr	Average Area m²/pr	Interpersonal Spacing ft	Interpersonal Spacing m	Description
A	13 or more	1.2 or more	4 or more	1.2 or more	Standing, circulation within queuing area passing, without disturbing others.
B	10-13	0.9-1.2	3.5-4	1.1-1.2	Standing, partially restricted circulation.
C	7-10	0.7-0.9	3-3.5	0.9-1.1	Standing, restricted circulation by disturbing others, "excuse me" zone..
D	3-7	0.3-0.7	2-3	0.6-0.9	Standing without contact possible, but movement is severely restricted and disturbing to others, Long-term waiting discomforting.
E	2-3	0.2-0.3	1-2	0.3-0.6	Standing without contact, movement within queue not possible. Threshold potentially dangerous crowd pressure.
F	2 or Less	0.2 or less	1 or less	0.3 or less	Close contact with all. Uncomfortable. and psychologically disturbing. Potential for shock waves in mass crows. falls, other hazards.

PLATFORM LOS

Like stairs, platforms have different functions and characteristics during departing and arriving peak conditions. For the arriving peak, the platform must have sufficient area and vertical access facilities for passengers to quickly move through it. During the departing peak, the platform acts as a storage area for passengers waiting for a train and as a movement space for passengers distributing themselves along the platform. TS analysis is useful for determining the average per person area available for these purposes, for comparison with the LOS standards. The net effective platform width is determined by deducting a 1.5-ft (0.45-m)-safety edge along the length of the platform and the footprint area of any stairs, columns, or other space-consuming features on the platform. There are a number of alternatives for the placement of stairs on platforms. Uniform spacing of stairs on the platform provides for a more even distribution of passengers, but the stairs take up more platform space. End locations allow wider stairs with no footprint on the platform, but walking distances are longer and uneven distribution of passengers occurs. TS analysis provides the means of analyzing various placement alternatives for stairs and the potential impact on pedestrian LOS. It also allows a section-by-section analysis of the platform where there are irregularly spaced stairs or variations in platform conditions, such as differences in occupancy.

Example: Determine the pedestrian LOS of a 600-ft (183-m)-long, 20-ft (6.1-m)-wide, side-loading transit platform for average and maximum load conditions and a train departure of 1500 passengers during a 5-min peak period. Evaluate the differences of (a) using two stairways, one at each end of the platform, and (b) using three stairways, one at either end and one in the center. Note that the average walking distance is half the maximum walking distance from either end of the platform.



Solutions: The platform will be evaluated using the TS method. The net effective area is determined by deducting the 18-in (457-mm) safety edge along the length of the platform and any stairway footprint. All the departing passengers will both walk and wait on the platform. Walk times are determined by the average walking distance from each stairway to the adjacent platform sections, and an assumed "restrained" walking speed of 3.3 ft/s (1 m/s). The average wait time, assuming that passenger arrivals on the platform are uniform, is half of the 5-min headway time, or 2.5 min. In alternative (a) there is no stairway footprint, but in alternative (b) the stairway footprint must be deducted from the net platform area, compensated by a reduction in average walking distances.

(a) Using two stairways

$$\begin{aligned} \text{Gross area platform} &= (20\text{ ft})(600\text{ ft}) = 12{,}000\text{ ft}^2 \\ \text{Less safety edge} &= (1.5\text{ ft})(600\text{ ft}) = \underline{-900\text{ ft}^2} \\ \text{Net effective area} &= 11{,}100\text{ ft}^2 \end{aligned}$$

$$\begin{aligned} \text{TS supply} &= (\text{net effective platform area})(\text{headway min}) \\ &= (11{,}100)(5\text{ min}) \\ &= 55{,}500\text{ ft}^2\text{–min} \end{aligned}$$

Average walk distance = (0.5)(300 ft) = 150 ft

Average walk time = $\frac{150}{3.33\,ft/s}$ = 45 s or 0.75 min

3.33 ft/s

Average wait time = (0.5)(headway) = (0.5)(5) = 2.5 min

TS demand = (no. passengers)(avg. walk time + avg. wait time)
= 1500(0.75 + 2.5)
= 4875 pr-min

Average platform area/passenger = $\frac{TS\,supply}{TSdemand} = \frac{55{,}500\,ft^2-\min}{4875\,pr-\min} = 11.3\,ft^2/pr$

At max. occupancy = $\frac{platformarea}{\max.passengers} = \frac{11{,}100\,ft^2}{1500\,psgrs.} = 7.4\,ft^2/pr$

Platform LOS at average occupancy, 11.3 ft^2 /pr
Walkway LOS D, queuing LOS B
Platform LOS at maximum occupancy, 7.4 ft^2 /pr
Walkway LOS E, queuing LOS D

Discussion: This is a functional, but very crowded platform. There are examples of more crowded platforms in the New York City transit system. The platform crowding could be improved by widening of the platform or by adding trains to reduce the passenger volume per arrival

(b) Using three stairways

Net effective platform area with 2 end stairs = 11,100 ft^2

Less footprint of center stair (11 ft x 16 ft) = -176 ft^2

Net effective area with 3 stairs = 10,924 ft^2

TS supply = (10,924 ft2)(5 main) = 54,620 ft^2 -min

TS demand: average wait time remains the same, average walking distance cut in half by center stair (from 150 ft to 75 ft), and average walk time from 0.75 main to 0.38 min.

Average platform area/passenger = $\dfrac{54{,}620\, ft^2 - \text{min}}{4320\, pr - \text{min}} = 12.6$ ft /pr

TS demand = 1500(0.38 + 2.5) = 4320 pr-min

Platform LOS at average occupancy, 12.6 ft^2 /pr

Walkway LOS D, queuing LOS B

LOS at maximum occupancy remains the same

Discussion: The addition of the stairway at the center of the platform reduces the time—space supply, but shortens walking distances. This impact is not sufficient to improve the platform LOS, but the TS analysis does show that the average level of crowding is reduced and passenger convenience is improved. In practice, it is known that passengers tend to cluster around platform access stairs, so the center stairway design will also result in a more even distribution of passengers on the platform. This also results in a more even distribution of passengers on the train, a desirable objective to improve passenger perceptions of service.

ESCALATOR AND MOVING WALKWAY LOS

Escalators and moving walkways are high-capacity, continuous-service mechanical aids that can facilitate vertical and horizontal pedestrian movement. Escalator and moving walkway technology has evolved over a period of 100 years, and there are examples of well-maintained escalator installations that have provided continuous service for more than 50 years. Photographic studies of escalator and moving walkway use indicate that escalator utilization and capacities are closely related to human factors such as shoulder width, personal space preferences, and ability to adjust to system speed. Even under heavy queuing, vacant steps can be observed on most escalators, with similar preferred personal spacing on moving walkways, rather than that assumed by the manufacturer. Most escalators in transit applications in the United States operate at a speed of 90 ft/min (0.45 m/s), but higher speeds are observed in Europe, reportedly more than 164 ft/min. The U.S. Code limits escalator speeds to 120 ft/min (0.60 m/s), and moving walkway speeds to 180 ft/min (0.91 m/s).

Escalators are preferred for vertical movement in transit applications because of their high capacity. It would take three or more large elevators to equal the capacity of a single escalator. Disadvantages of escalators are that they take up significant space, are not accessible to wheelchair users, and, because of their 30° slope, may be difficult to integrate with other movement facilities such as elevators. Escalators and moving walkways tend to experience more accidents than elevators because of the direct exposure of passengers to moving elements of the system, passenger difficulties in adjusting to escalator and walkway movement, and their mechanical discharge characteristic. Escalators and moving walkways will continue to mechanically discharge passengers until stopped. This has resulted in accidents where there is limited landing area to disperse exiting passengers or where the discharge end of the escalator cannot be cleared quickly enough for some reason. Since escalators and walkways can mechanically discharge up to 90 persons/min and these persons minimally require at least 5 ft2/pr (0.5 m2/pr) each to move away from the escalator, it can be seen that even a temporary blockage at the discharge end of an escalator can create a large demand for circulation space. Escalator data and theoretical and practical design capacities are shown in Table 8-4.

Estimates of moving walkway use can be developed from Eq. (8-1) by using the speed of the walkway and assuming the average standing area of passengers, or by the TS method, Eq. (8-3), if it is necessary to determine attainable capacities where there is a mix of standing and walking passengers.

TABLE 8-4

Theoretical and Nominal Escalator Capacities

Width at Hip		Width at Tread		**Theoretical** Capacity	**Nominal** Capacity	
in	mm	in	mm	pr/hour	pr/h	pr/min
				5000	2040	34a
32	813	24	610			
				6700	2700	45b
				8000	4080	68a
48	1219	40	1016			
				10,700	5400	90b

aIncline speed of 90 ft/min (0.45 m/s), 68 steps/min
bIncline speed of 120 ft/min (0.60 m/s), 89 steps/min

Example: Determine the practical capacity of a 300-ft (81.5-m)-long (1), 120-ft/min (0.6-m/s), 4-ft (1.2-m)-wide (w) moving walkway under the assumption that half of the passengers stand and half walk at a speed of 3 ft/s.

Solution: There are two types of passengers on the moving walkway, standees who occupy less space but are on it for a longer time and walkers who need more space and who are on it for a shorter time. To solve the problem it is necessary to assume the space needed by standees and walkers. For purposes of this example, a crowded moving walkway at 7 ft^2/pr (0.7 m^2/pr) for standees and 20 ft^2/pr (1.9 m^2/pr) for walkers is assumed. The capacity per minute, T = 1 min, will be determined.

n1 = standees, $a_1 = 7\ ft^2/pr$, $t_1 = 300\ ft/2\ ft/s = 150\ s$ or 2.5 min

n2 = walkers, $a_2 = 20\ ft^2/pr$, $t_2 = 300\ ft/(3 + 2\ ft/s) = 60s$ or 1 min

N = capacity (p/min), $n_1 = 0.5N$, $n_2 = 0.5N$

From Eq. *(8-3)*,

$(a_1 n_1 t_1) + (a_2 n_2 t_2) = 'wlT$

$(7)(0.5N)(2.5) + (20)(0.5N)(l) = (4)(300)(1)$

$8.75N + 10N = 1200$

$18.75N = 1200$

N = 64 pr/min, practical capacity of walkway

ELEVATOR LOS

Elevators have had limited application in transit stations, except for vertical movement of physically impaired persons. Their use has not been more widespread because elevators generally have less movement capacity than escalators and stairs and because users must wait for elevator arrivals. It would take a group of three or more large elevators to equal the capacity of a single escalator. Elevators have the advantage of fast trip times, lower accident rates than escalators, and, in some installations, lower life- cycle cost. Other advantages of elevators are that they provide for bidirectional movement and standby service where there is a mechanical failure of one unit in a group. From a station planning viewpoint, elevators simplify the location of vertical movement access and fare control areas as compared to inclined escalators.

Elevators should receive greater consideration as a vertical movement alternative in transit stations particularly since at least one elevator is required for the needs of the physically impaired. The elevator alternative should be examined for deep stations where escalator trip times are long and for outlying stations where passenger volumes are likely to be lower. Escalator trip times in deep stations can exceed 2 min, whereas the comparable trip by elevator could be less than 30 s, excluding waiting time. It is not unusual to see the non-physically-impaired competing to use the elevator in the deeper stations of the Washington, D.C., Metro transit system to avoid longer escalator trip times. Elevators can be programmed to meet an arriving train to help offset the waiting time disadvantage.

Elevator capacity is determined by the floor or standing area of the cab, average speed allowing for acceleration and deceleration, and dwell times for the loading and unloading of passengers, plus the opening and closing of doors. Elevator travel speeds of up to 1,800 ft/min (9 m/s) have been attained in high-rise building applications, but a speed of about 400 ft/min is the more likely maximum for transit stations. Approximate estimates of elevator capacity for preliminary planning purposes can be developed by assuming cab standing areas at 2 ft2/pr (0.2 m2/pr), an allowance of 10 s for each cab acceleration and deceleration set, 10 s for each door opening and closing set, and the travel speed of the elevator. Elevator suppliers should be consulted if preliminary estimates indicate that an elevator alternative to escalators may be feasible. They have elaborate computer simulation programs that would confirm the relative service statistics of the two alternatives.

Example: Determine the number of elevators required to meet a peak-period train discharging 150 passengers at an outlying station. The station has a 50-ft (15.2-m) rise. Compare with the alternative of a 48-in (1220-mm) nominal-width escalator operating at a speed of 90 ft/min (0.45 m/s) and with a practical capacity of 68 pr/min or 1.1 pr/s.

Solution: As a trial assumption, three large elevators with a cab area of 50 ft2 (0.5 m2) will be used. The standing passenger capacity of these elevators at 2 ft2/pr would be 25 persons. Dwell time to load and discharge passengers via double opening doors at a headway of 1 s/pr/door would be about 13 s. The shaft time or elevator travel time for the 50-ft trip at a speed of 400 ft/min would be 8 s, with the addition of approximately 10 s for each acceleration and deceleration set and 10 s for each door opening and closing set.

The three elevators would be programmed to meet the arriving train, pick up 75 passengers, and return for the remaining 75. The trip time for the first group of passengers unloaded at the surface would be:
2 (13 s) load/unload + 8 s travel + 10 s accel/decel + 10 s door close/open = 54 s
The trip time for the first person using the escalator to reach the surface would be
100 ft slope/1.5 ft/s = 67 s
The seventy-fifth escalator passenger would reach the surface after 2 min. The maximum wait for the second group of 75 elevator passengers left on the platform after the first pickup would be
54 s + 10 s door close /open + 8 s travel + 10 s accel/decel = 82 s
This compares with the average waiting time of about 1 min experienced by 150 passengers boarding an escalator with a capacity of 68 pr/min.

The total time for the second group of 75 elevator passengers to reach the surface level would be
· 10 s accel/decel = 136 s
This compares with the time for the last escalator passenger to reach the surface of
67 s + 150 pr/1.1 pr/s = 203 s

The people movement capacity of the three elevators is

150 pr/136 s = 1.1 pr/s

exactly the same as the escalator.

Discussion: The theoretical analysis shows that overall passenger service statistics for the three elevator alternative are comparable to the escalator. The movement capacity in pr/s for the three large elevators is 150/136 s = 1.1 pr/s, equal to the escalator. The elevators have a faster total delivery time than the escalator. Escalators are viewed by many as continuous-service, no-wait systems. But the short-term capacity of the escalator would be exceeded even with the relatively low demand of 150 train passengers. This results in a wait to ride the escalator, which should be considered in comparing the service of the two alternatives. In the long term the three elevators could have functional and life-cycle cost advantages, particularly considering that a mechanical failure of the escalator would have serious consequences. The failure of one elevator would still leave two available at reduced levels of service.

PLANNED PEDESTRIAN SYSTEMS

There is much evidence of a growing awareness of pedestrian needs. The benefits of urban pedestrianization include reduced air, noise, and visual pollution and reduced pedestrian accidents and other improvements in the quality of life. Pedestrianization has many forms including auto-free zones and malls within existing city street systems, vehicle-free business or activity centers, elevated pedestrian "skyway" systems, and underground networks. Skyway systems have been built in such cities as London, Minneapolis, and Cincinnati, and underground networks in Montreal, Tokyo, Houston, and New York.

The classic approach to pedestrian improvements is the separation of the pedestrian from the vehicle either by space or time. Traffic signalization represents an example of separation of pedestrians and vehicles in time, but pedestrians are still exposed to turning vehicles. Traffic signalization also has the disadvantages of causing pedestrian delay, queuing at crosswalks, and the creation of denser platoons of pedestrians than would normally occur in uninterrupted free flow. The spatial separation of pedestrians and vehicles, either horizontally by pedestrian malls or vertically through elevated or underground pedestrian convenience networks, represents the ultimate improvement objective, but more modest improvements can be quickly and inexpensively attained.

There is a high pedestrian-accident exposure due to vehicles turning through crosswalks while people are crossing. Many cities already have extensive vehicle turn restrictions in downtown areas, but they are not planned on a systemwide basis. This may not cause as much hardship to motorists as might be thought since the predominant downtown vehicular movement is the through one.

Low-capital improvements include upgrading pedestrian circulation, better street lighting, and standardization of street furniture and signs. Improved circulation is attained by special pedestrian signal cycles and vehicular turn restrictions, sidewalk widenings through the use of building setbacks and arcades, better location of street furniture, and shortening of walking distances by means of midblock connectors. The control of street furniture location is necessary to provide maximum clear width on sidewalks and to eliminate obstructions in the vicinity of crosswalks, particularly those that can obscure the turning driver's view of pedestrians. Street lighting improvements upgrade area image and significantly reduce pedestrian accidents and street crime. Many cities have found that lighting improvement programs receive quick popular support and even supplementary private financing on a voluntary basis. Additionally, the change to more efficient modern luminaires often results in reductions in total energy use.

Building setbacks, arcades, pedestrian plazas, and other such amenities can be obtained by bonus zoning amendments that allow larger building areas to developers who provide them. When pedestrian plazas are provided by private developers, care must be taken that the improvement is carefully integrated into the pedestrian system. Above- or belowgrade building plazas do not add to sidewalk capacity and may actually isolate and inconvenience some pedestrians.

The pedestrian mall is becoming a common improvement, but it must be carefully planned to be successful. The requirements for a viable mall program include complete exclusion of all but emergency vehicles; development of adequate perimeter street capacity to replace that eliminated by the mall; provision of adequate transit and highway access and sufficient parking; upgraded street lighting; and the development of an active and cooperative promotional program based on aesthetic improvements, special events, and coordinated advertising. The locations of walking trip generators must be considered when planning malls. Transit operations within the mall can discourage walking trips and exposure to retail edges, whereas strategically located stops at the ends of the mall can encourage walking and retail exposure.

The ultimate pedestrian improvement program is the grade separated pedestrian convenience network. These networks are being built above or below street level, depending on local requirements. The network aspect, particularly the need for continuity within these systems, must be emphasized. New York City has several miles of underground passages serving individual buildings and subway stations. Because these are not interconnected, their use is limited except in the most inclement weather. This is in sharp contrast to the well-planned and heavily utilized 3.6-mi (6-km) underground system in Montreal, Canada.

Underground systems need only be about 10 ft (3 m) below street level to provide full weather protection and efficient climate control. They can be easily connected to subway transit stations. Disadvantages of underground systems include their high construction costs, possible conflicts with subsurface utilities, and loss of visual identity with the cityscape above. Aboveground pedestrian convenience networks have the advantage of lower construction costs and greater opportunities for integration and identification with the cityscape. The primary disadvantage of aboveground networks is that their greater height above street level, required to provide vehicle clearances, makes them difficult to relate to belowground transit. Both systems provide the developer or owner with added valuable commercial space.

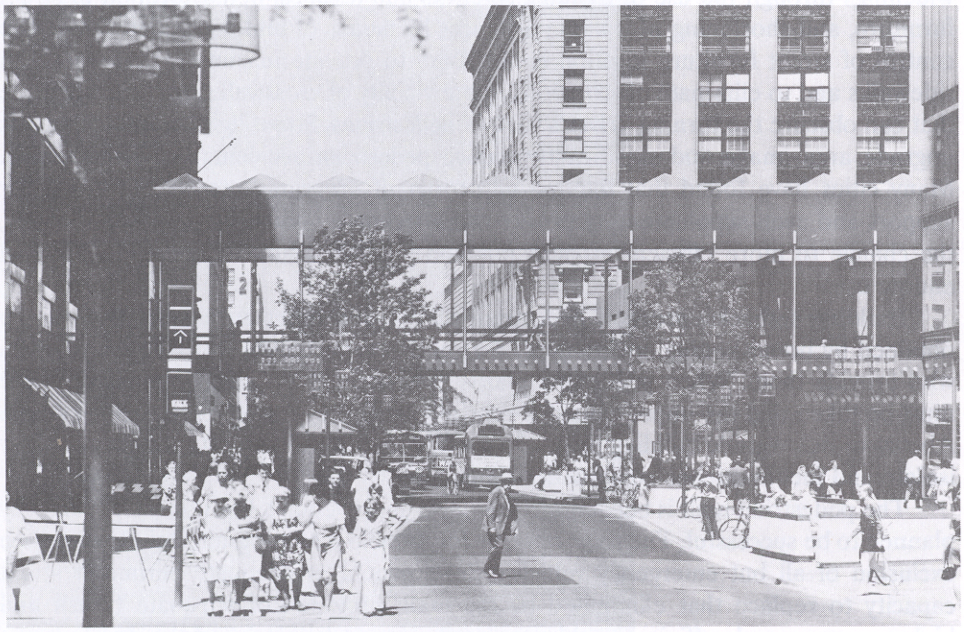


Figure 8-3 *Pedestrian transit mall and skyway—Nicollet Mall, Minneapolis. The Minneapolis skyway system consists of an elevated network of connecting bridges and passageways serving many of the major buildings in the downtown areas. (courtesy of Greater Minneapolis Chamber of Commerce)*

Pedestrian system planning in transportation terminals and stations follows the same basic pedestrian improvement objectives but requires greater consideration of the heavy pedestrian traffic movements typically occurring in these facilities, the magnified value that the traveler is likely to place on time and delay, and the increased need for information and orientation. Also, transportation planners rarely examine the effectiveness of the external walkway network surrounding a transportation terminal or station. The service area of transit, and therefore its potential utilization, could be increased by more effective planning of this external pedestrian system. Pedestrian processing times through transportation terminals should be minimized because of the tendency of the passenger to magnify this time over the equivalent time spent in transit. This human tendency for exaggeration of time spent making intermodal transfers has been noted by transportation system analysts, with some applying a factor of 2.5: 1 for time spent in a station.

Figure 8-4 *Place Bonaventure, Montreal, Canada. Smart shops line three levels of corridors in a giant merchandising mart in the heart of the city. The mart is part of the Montreal underground pedestrian network that connects major transportation lines and many of the hotels and major retail establishments in the downtown area. (courtesy of City of Montreal)*

Deep subway systems have been built on the basis of construction cost savings without consideration of the value of pedestrian time that is spent, over the life of the system, traveling to and from the surface and platform level. In some deep stations this can involve an escalator ride of more than 2 min. Passenger orientation, information, and way-finding convenience are also important transportation terminal design objectives.

The physically impaired must be considered in the design of all pedestrian systems. Surveys in the United States indicate there are at least 20 million Americans with disabilities severe enough to restrict or discourage their use of public transportation or their finding employment commensurate with their qualifications. Many others with what might be termed minor sight, locomotion, or other impairments are inconvenienced daily by design features that do not consider these common disabilities.

The ranks of the physically disadvantaged are also expanding at a rate faster than the growth of the general population because medical advances are continually increasing survival rates from accidents and illness and extending life spans of the aged. The very heavy automobile accident rate in this country is a contributor to the ranks, with the added reminder that anyone, despite present physical and mental capabilities, can become disabled at any time and possibly rendered inoperable in a society ordered only for the most physically fit.

There are other types of impairments that designers sometimes overlook. Passengers in transportation terminals are likely to be physically encumbered by baggage, and subway users by parcels and even heavy winter clothing, a factor that should be considered in designing doorways, turnstiles, stairs, and other similar human interface features. This means that the proportion of physically disadvantaged users in most transportation and building systems constitutes a larger population than is generally realized.

While some may believe designing systems with consideration of the physically impaired is a highly idealized, impractical, and costly philosophy, it is not true. The needs of these persons are only a magnification of the problems that face all system users. By recognizing these needs, designers can project themselves more easily into the problems of all users, creating designs with greater general utility. On the other hand, design-imposed dysfunctions can limit the economic life and viability of building and transportation systems by continual daily inconvenience. Consideration of the needs of the disadvantaged users of a system is not an idealistic design objective, but a pragmatic approach to producing more utilitarian systems for all.

SUMMARY

Walking is a unique transportation mode connector and a key determinant of many aspects of urban quality of life. Transit station planning and design require a careful analysis of the movement of people. Pedestrian facility organization and adequacy within transit stations determine user perceptions of service, convenience, and passenger safety. This chapter provides the basic analytical tools needed to determine new station requirements and adequacy of existing facilities. Two methods of analysis are presented. Level-of-service standards provide qualitative measures for the design and evaluation of simple walkway, stairway, and queuing spaces. The time—space analysis technique provides a means of analyzing more complex pedestrian spaces. Examples include platforms, fare-control areas, and corridor intersections. The capacity and application of escalators and elevators is also discussed. Simple solved problems are presented to illustrate methods of analysis for a variety of pedestrian facilities.

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EXERCISES

(a) Measure the area of an elevator cab floor and record your observations of pedestrian areas, convenience, and behavior during a number of elevator trips; compare to LOS and discuss.

(b) Measure the area of a busy street corner and record your observations of pedestrian areas, convenience, and behavior during a number of light cycles; compare to LOS and discuss.

8-2 Conduct walking-speed studies of people walking to a transit stop and people in a shopping mall. Discuss differences in observed speeds and behavior.

8-3 Record your personal walking distances for your different activities during a typical day. Discuss reasons for the long walking distances occurring in large cities.

8-4 Determine the pedestrian LOS for a 10-ft (3-m)-wide corridor (wall-to-wall) and a 6-ft (1.8-m)-wide stair (clear distance between handrails) for a volume of 500 pedestrians during a 5-min peak period. Discuss the differences in LOS and problems at the stair approach at the point where the two intersect.

8-5 Two 16-ft (5-m)-wide corridors intersecting at right angles will be accommodating a forecasted demand of 750 multidirectional pedestrians in a 5-min peak period. Walking speed through the intersection is estimated at 3.3 ft/s (1 m/s) and average occupancy time in the intersection at 6 s, or 0.1 min. Using the TS method, determine the average ft^2/pr(m^2/pr) and LOS for the intersection.

8-6 For Exercise 8-5, determine the sensitivity of the design to changes in predicted occupancy times to 10 and 12 s. Discuss.

Figure 8-5 *Chicago Transit Authority Terminal Station at O'Hare Airport, Chicago. (courtesy of Harre W. Demoro Collection)*

Figure 8-6 *San Francisco Transbay Transit Terminal. (courtesy of California Department of Transportation)*